## Generating world price functions for the Chinagro model: the use of GTAP

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2011

**Generating world price functions for the Chinagro model: the use of GTAP**

*CATSEI project*[1]

*Work Package 2, deliverables D12/D13*

by

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*(Concept version, May 2011)*

[1] CATSEI is a multidisciplinary research project funded by the European Union under its Sixth Framework Programme. Cooperating partners in the project are the Centre for World Food Studies, Amsterdam (SOW-VU), the Center for Chinese Agricultural Policy, Beijing (CCAP), the International Institute for Applied Systems Analysis, Laxenburg (IIASA), the School of Oriental and African Studies, London (SOAS), the Agricultural Economics Research Institute, The Hague (LEI), and the International Food Policy Research Institute, Washington DC (IFPRI).

## 1. Introduction

Since the gradual opening up of China to international agricultural trade, the country has assumed a large role in international agricultural trade, on one hand as exporter of fruits, vegetables and fish, on the other hand as importer of dairy, sugar, vegetable oils and animal feeds, in particular protein-rich feeds. For staple food, current trade flows are relatively small but the mere size of its economy may easily leads to large shocks on world markets in case of domestic supply-demand imbalances. Therefore, economic analysis cannot neglect the impact of changes in China's foreign trade volumes on international food and feed prices. This report describes how these price reactions are taken into account in the CATSEI project.

The overall object of the CATSEI project is to investigate the impact of China's current economic transition on its agricultural economy, with special reference to the consequences for international trade, farm incomes and environmental pressure. The project opts for a quantitative approach in which findings from separate analyses in the three fields are integrated into a general equilibrium welfare model. In this respect, the project does not start from scratch but builds upon the Chinagro model, developed in an earlier EU-funded project of the same name.

The Chinagro model is a geographically detailed model that comprehensively depicts China's farm sector in more than 2800 counties, while connecting these through trade and transportation flows to each other, to rural and urban consumers and to abroad. Scenario simulation covers the period 2005-2030 and analyzes the future of the agricultural economy under alternative exogenous trends for a wide range of driving variables such as non-agricultural output, demography, migration, international price trends, available crop and grass land, technical progress and government tax and tariff policies. Fischer et al. (2007) provides an overview.

In the original version of the Chinagro model, developed in the earlier EU-funded CHINAGRO-project, foreign trade prices are fully exogenous. But one of the specific purposes of the CATSEI-project (in particular, its Work Package 2) is to replace this exogenous specification by functions that reflect the international price reactions to changes in China's agricultural trade volumes. In this report we will describe the derivation of these world price reaction functions. Since specific evidence is hard to be discerned on the basis of historical trade and price trends, a quantitative simulation model of world trade will be used to generate observations on international prices for alternative levels of China's trade volumes.

To generate these observations, the GTAP (Global Trade Analysis Project) model seems the most appropriate model, due to its worldwide coverage, its regularly updated data base, its general equilibrium character with price impacts across different commodities, and its widespread use in international agricultural policy analysis. The basic structure of the GTAP-model is described in Hertel (editor, 1997). Other models of international agricultural markets such as those used for the annual projections of the Organization of Economic Cooperation and Development and the Food and Agricultural Organization (OECD-FAO, 2008), the United States Department of

Agriculture (USDA, 2008) and the Food and Agricultural Policy Research Institute (FAPRI, 2008) are not or not easily accessible to outside users. The same applies to the IMPACT model used by IFPRI, the International Food Policy Research Institute (Rosegrant et al, 2001).

In principle, having selected a functional form for the world price reaction functions, our approach is as follows: (i) generate a sample of China-specific trade volume shocks, (ii) calculate the corresponding world prices from GTAP simulations, and (iii) use these observations to estimate the reaction functions. Ideally, the interaction across agricultural markets would be captured by working with a vector-valued reaction function, estimating simultaneously own price effects and price effects across commodities. However, several complications make it advisable to execute the process in stages, gradually building up experience in connecting the two models.

First, Chinagro and GTAP operate with different commodity classifications. These differences will be expressed in a mapping matrix that allows transformation of Chinagro volumes into GTAP volumes and, reversely, transformation of GTAP prices into Chinagro prices. This mapping matrix will also cover differences in processing levels of the agricultural commodities, viz. by treating these differences as non-agricultural inputs.

Secondly, the commodities are aggregates, as always in applied modeling regardless of the type of model. This characteristic implicitly leads to perfect substitution across subgroups within the same commodity, which means that price reactions may be dampened. Hence, one has to be careful in interpreting the results for broad, heterogeneous commodities.

Thirdly, apart from these ‘normal’ differences, one has to cope with a fundamental discrepancy between the two models regarding classification of commodities from different countries. Chinagro focuses on the contents of the commodities, implying e.g. that rice from China and rice from US are considered as the same commodity traded on a single world market, unless differences in quality or other characteristics would make this assumption implausible. In this approach import (c.i.f.) and export (f.o.b.) price differences are explained from trade and transportation margins, as well as from differences in processing levels. In contrast, GTAP considers commodities from different countries by definition as different commodities, and, therefore, has separate international markets for rice from China and rice from US. In this approach the ‘world market’ consists of a full set of bilateral flows, with prices related to each other merely via the substitution effects on demand and supply side in each country.

This difference in approach is a major complication since GTAP turns out to have a rather strong separation between domestic and foreign commodities, apparently due to low substitution effects. This leads not only to significantly different price reactions of domestic and foreign varieties, but also to widely different intensities of the effects of import and export shocks. We will try to bridge the gap between the two approaches by estimating kinked price functions for the Chinagro commodities, with separate branches for import and export side.

Fourthly, the reaction functions are evidently not constant over time. In situations of relatively abundant supply, price responses will be lower than under tight market conditions. Therefore, it may be necessary to distinguish several reaction functions depending on different exogenous international market conditions, such as worldwide non-agricultural growth trends, acceptance of biofuel blending policies, technological progress and achievements of trade negotiations.

Finally, as documented in recent publications such as Cotula et al. (2009), China is trying to secure part of its future imports by buying agricultural land in other countries and continents. Although it is difficult to obtain an accurate picture of the amounts of land currently involved and the share of future import demand that will come from these areas, this policy of 'land grabbing' may well have a downward influence on China's impact on world prices.

Given these complications, this report keeps actual estimation confined to single-commodity equations (commodity by commodity), leaving estimation of cross-commodity price effects to a subsequent stage. Nevertheless, it already paves the way for this next stage by gathering experience from the outcomes of the single-commodity equations, by describing the impact of specific multi-commodity shocks such as shocks in all grain or all meat commodities together, and by outlining the multi-commodity estimation process.

The estimation outcomes will be judged not only on their statistical significance but also on their intrinsic plausibility. Whenever possible, the outcomes are compared to evidence from other studies such as the OECD-FAO, USDA, FAPRI and IFPRI studies mentioned above. Special attention is paid to the composition of Chinese vegetable and fruit exports.[2] Thus, this study has two sides: formal estimation based on GTAP simulation and use of evidence from the literature.

Once established, the price reaction functions will be used in stand-alone simulation of the Chinagro-model leading to outcomes for the domestic economy, as well as foreign trade volumes. The latter can then be reinserted into the international GTAP model to trace the consequences of specific scenarios for different regions in the world, if desired so.

The outline of the report is as follows. Section 2 explains the specification of the price reaction functions and their linkage to the Chinagro model. Section 3 discusses the mapping between Chinagro and GTAP. Section 4 analyzes GTAP simulation outcomes of single-commodity shocks in China's trade volumes. Section 5 uses these shocks to perform single-commodity (least squares) estimations. Section 6 discusses the effects of multi-commodity shocks as compared to single-commodity shocks. Section 7 compares the outcomes to evidence from other studies and explains the actual use of the (single-commodity) functions in the Chinagro model. Finally, section 8 summarizes. Several annexes are attached, covering Chinagro classification, GTAP classification, mapping matrix, model convergence, derivation of the functions and outline for the (next stage) multi-commodity estimation process, respectively.

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[2] In a separate activity, the CATSEI-project conducts commodity-specific trade studies on fruits and vegetables.

## 2. The world price reaction functions and their linkage to the Chinagro model

The world price reaction functions are based on welfare maximization by all countries other than China. To simplify the specification, these countries are not distinguished individually and not even classified by region or type of economic system but considered as one aggregate, i.e. the Rest of the World. As explained in Ginsburgh and Keyzer (2002)[3], the net imports of the Rest of the World can be derived from maximization of its trade welfare function subject to its budget constraint.

In principle, incorporation of the world price reactions in the Chinagro model can be done in two ways, viz. inside or outside China's welfare optimization. However, these two options reflect essentially different views on China's economic planning, as explained in Keyzer (2007). The first option means that China takes world prices as given and does not plan to influence them deliberately, whereas the second option means that it strategically plans its imports and exports including their influence on world prices. We consider the first option the most realistic description of China's recent and future agricultural economic policy. Thus, the Chinagro model is considered as part of a system of world models in which all countries maximize their welfare at given world prices. In this system only the Chinagro model is specified explicitly, the other models are represented by their joint trade welfare function.

Here, we show the system for a stylized version of the Chinagro model, capturing the relevant characteristics in terms of domestic and foreign trade. The full description of the Chinagro model (including regional markets and county-specific supply specification) can be found in Keyzer and Van Veen (2005).

First, we give the (stylized) description of the Chinagro model. Actors are indicated by index $i$ ($i = 1,...,m$), commodities by index $k$ ($k = 1,...,n$) and supply types by index $j$ ($j \in J$). There is one non-agricultural commodity, viz. $k = n$. Furthermore, we denote the country's commodity imports as vector $m$ and its commodity exports as vector $e$. In addition to revenues from supply, actors have income from exogenous endowments $\omega_i$. Their utility follows a quasi-linear specification, in which private consumption vector $x_i$ gives utility according to the non-linear function $u_i$ whereas for non-agriculture there is an additional linear utility component $x_{in}^q$. The latter is specified as fixed proportion $\sigma_{in}$ of the nationwide endogenous total $c_n$. At given domestic supply vectors $y_j$, given welfare weights $\alpha_i$ and given import and export price vectors $p^m$ and $p^e$, the (stylized) current version of the Chinagro model can then be represented by maximizing social welfare subject to the agricultural and non-agricultural commodity balances and the balance of payments constraint (which imposes an exogenous level $\Pi$ as upper bound on the net trade deficit):

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[3] Section 4.4.2

$$max_{x_i, x_i^q, c_n, e, m \geq 0} \sum_i \alpha_i u_i(x_i) + \bar{p}_n \sum_i x_{in}^q \tag{2.1}$$

*subject to*

$$\sum_i x_{ik} + e_k \leq \sum_i \omega_{ik} + \sum_j y_{jk} + m_k \qquad k = 1,...,n-1 \qquad (p_k)$$

$$\sum_i (x_{in} + x_{in}^q) + e_n \leq \sum_i \omega_{in} + \sum_j y_{jn} + m_n \qquad (p_n)$$

$$x_{in}^q = \sigma_{in} c_n \qquad i = 1,...,m$$

$$x_{ik}^q = 0 \qquad k = 1,...,n-1$$

$$p^{mT} m - p^{eT} e \leq \Pi \text{ [4]} \qquad (\rho)$$

given $\alpha_i \geq 0$ $\qquad i = 1,...,m$

$$\sigma_{in} \geq 0, \quad \sum_i \sigma_{in} = 1$$

$$p_k^m > p_k^e > 0 \qquad k = 1,...,n-1$$

$$\bar{p}_n = p_n^m = p_n^e$$

The Lagrange multipliers $p_k$ associated to the commodity balances represent the market prices in the domestic economy. The first-order conditions of the welfare program show how these domestic prices are related to the exogenous import and export prices:

$$p_k \leq \rho p_k^m \quad \perp \quad m_k \geq 0 \qquad k = 1,...,n-1 \tag{2.2a}$$

$$p_k \geq \rho p_k^e \quad \perp \quad e_k \geq 0 \tag{2.2b}$$

where symbol $\perp$ denotes complementarity. Due to the inclusion of the linear non-agricultural utility component and the assumption of equality of the exogenous non-agricultural import and export price, the shadow price of the balance of payments constraint $\rho$ is equal to one.[5] Hence, in case of imports the domestic price equals the import c.i.f. price, in case of exports it equals the export f.o.b. price and in case of autarky it is somewhere in between. In fact, the relations in the actual Chinagro model are richer due to the prevalence of trade and transportation margins and tariffs.[6] However, unless committed trade flows are imposed, neither the stylized nor the actual Chinagro model has simultaneous imports and exports for the same agricultural commodity in the same period, since $p_k^m > p_k^e$. For the non-agricultural commodity, the situation is different: first, only the net foreign trade flow can be distinguished (since import and export price are assumed to

[4] Superscript *T* indicates (vector or matrix) transpose, hence $p^{mT}$ is the transpose of $p^m$ (similar for $p^{eT}$).

[5] In fact, $\rho$ is only equal to one as long as $c_n > 0$, but this condition is satisfied in the empirical situations that the Chinagro model considers.

[6] Furthermore, the actual Chinagro model operates at the level of eight regional markets instead of one national market and expresses domestic and foreign prices in different units (imposing an exogenous exchange rate).

be equal), and, secondly, $\rho = 1$ implies that $p_n = \overline{p}_n$. This equation acts as price normalization rule of the model.

Specification (2.1) and hence equations (2.2) remain unaltered when the world price reaction function is added. Following the approach in Keyzer (2007), this function is specified as a vector-valued function that describes world agricultural prices $p^w \in R_+^{n-1}$ as depending (negatively) on China's net agricultural import volumes $z \in R_+^{n-1}$ and the non-agricultural world price $\overline{p}_n^w$:

$$p^w = \overline{p}_n^w \, U'(-z) \qquad (2.3)$$

Here, $U$ is a strictly concave increasing function from $R_+^{n-1}$ to $R$. Relation (2.3) can be derived by assuming a quasi-linear trade welfare function for the Rest of the World (ROW) and maximizing its value subject to the corresponding balance of payments constraint:

$$\begin{aligned} &\max_{\tilde{z}_k} \quad U(\tilde{z}_1, .., \tilde{z}_{n-1}) + \tilde{z}_n \\ &\textit{subject to} \\ &\sum_{k=1}^{n-1} p_k^w \tilde{z}_k + \overline{p}_n^w \tilde{z}_n \leq \tilde{\Pi} \end{aligned} \qquad (2.4)$$

with $\tilde{z}_k = -z_k$ for $k = 1,...,n-1$ denoting ROW's net import and $\tilde{\Pi} = -\Pi$ its trade deficit. The quasi-linearity makes this net import independent of its income and consequently independent of $\Pi$.

As the world price functions express world agricultural prices (relative to the price of nonfood) as a function of China's net import volumes, this specification allows for cross-commodity effects, covering worldwide substitution on both supply and demand side. Finally, we have to specify the margins between the world price and China's trade prices. It is done in a simple linear way:

$$p_k^m = p_k^w + \tau_k^w \qquad k = 1,...,n-1 \qquad (2.5a)$$

$$p_k^e = p_k^w - \tau_k^w \qquad (2.5b)$$

for positive coefficients $\tau_k^w$, while $p_n^m = p_n^e = \overline{p}_n^w$.

The extended Chinagro model now consists of program (2.1), equations (2.3) and equations (2.5). The solution of the system must be obtained by iteration over the world prices so as to make the solution of the Chinagro model consistent with the world price reaction function. In other words, the Chinagro model is solved with equations (2.3) and (2.5) as feedback rule. Based on the outcomes $z$ of the Chinagro model at given trade prices $p^m$ and $p^e$, new world prices are calculated using (2.3), leading via (2.5) to new trade prices, and the Chinagro model is solved again until convergence of the trade prices. Annex 4 discusses existence of the solution of the extended model and convergence of the solution algorithm.

As functional form, we use the quadratic form $U : R^{n-1} \rightarrow R$,

$$U(v) = b^T v - \frac{1}{2} v^T A v \tag{2.6}$$

with $b \in R_{++}^{n-1}$ and matrix $A$ of size $(n-1) \times (n-1)$, symmetric and strictly positive definite. Then, the derivative satisfies $U'(v) = b - Av$, and consequently, the price function reads $p^w = \overline{p}_n^w (b + Az)$, i.e. is linear with a positive intercept.

While one may argue that a linear relationship is not the most appropriate formulation since the marginal effects of trade shocks are constant, a linear approximation with non-zero intercept offers a practical option that is often used in demand models as well. Nonetheless, we will have to check the plausibility of the resulting pattern of price responses and apply further refinements of the function, if deemed necessary.

Furthermore, as mentioned already in the introduction, the resulting equation cannot be assumed to be invariant under alternative developments of the international market conditions. Therefore, it may be necessary to distinguish separate functions for different exogenous international trends, possibly including time-dependent parameter adjustment rules.

## 3. Mapping between Chinagro and GTAP

The commodity classification of the Chinagro model is given in Annex 1. As background to the analysis of the trade shocks, Table 3.1 shows our estimates of China's agricultural trade volumes in 2004 by Chinagro commodity, as well as total world trade.

Table 3.1 Agricultural trade volumes 2004, by Chinagro commodity

| Commodity | Export China | Import China | Net import China | World trade |
|---|---|---|---|---|
| Milled rice | 1000.0 | 250.0 | -750.0 | 28000.0 |
| Wheat flour | 777.8 | 7777.8 | 7000.0 | 118035.0 |
| Maize | 3278.0 | 588.1 | -2689.9 | 85100.0 |
| Other staple food | 795.3 | 3181.0 | 2385.8 | 10676.0 |
| Vegetable oil | 434.9 | 8697.1 | 8262.3 | 60276.0 |
| Sugar | 160.3 | 1603.1 | 1442.8 | 42786.0 |
| Fruits | 2966.7 | 445.0 | -2521.7 | 58700.0 |
| Vegetables | 6283.0 | 1256.6 | -5026.4 | 52000.0 |
| Ruminant meat | 42.9 | 142.9 | 100.0 | 9821.8 |
| Pork | 642.9 | 192.9 | -450.0 | 7735.0 |
| Poultry meat | 428.6 | 128.6 | -300.0 | 10278.0 |
| Milk | 226.7 | 2266.7 | 2040.0 | 79551.0 |
| Eggs | 71.4 | 21.4 | -50.0 | 1640.0 |
| Fish | 2235.4 | 670.6 | -1564.8 | 49500.0 |
| Carbohydrate feed | 5410.3 | 21641.1 | 16230.9 | 92133.0 |
| Protein feed | 4434.1 | 88681.3 | 84247.2 | 453296.0 |

Units: 1000 ton (food including maize) or 1000 Mcal (feed)

One may observe that, in terms of net trade flows, the largest shares are found for the aggregated commodity 'other staple food' (covering food tubers, minor food grains as well as soybeans and groundnuts directly sold to households), with a net import share of 22% of world trade, and for carbohydrate feed and protein feed, with net import shares of around 18% each. On the other hand, shares are only around 3% or lower for rice, maize, sugar and most livestock products.

The contributions of each commodity to the balance of payments are shown in Table 3.2. In this table the country's huge trade surplus stands out, with a total of 49.3 billion US dollar in 2004. Compared to this total, the agricultural trade volumes seem rather small. Together, the agricultural Chinagro commodities account for a net trade deficit of 4.7 billion dollar, the largest amounts being paid for vegetable oils and protein feed, whereas vegetables, fruits and fish are the main earners of foreign exchange.[7]

Table 3.2 Net export volumes and values of China, 2004, by Chinagro commodity

| Commodity | Volume in 1000 mton (food) or 1000 Mcal (feed) | Price in USD per kg (food) or Mcal (feed) | Value in million USD |
|---|---|---|---|
| Milled rice | 750.0 | 0.291 | 218.4 |
| Wheat flour | -7000.0 | 0.204 | -1426.3 |
| Maize | 2689.9 | 0.122 | 327.3 |
| Other staple food | -2385.8 | 0.300 | -715.7 |
| Vegetable oil | -8262.3 | 0.544 | -4494.3 |
| Sugar | -1442.8 | 0.233 | -335.5 |
| Fruits | 2521.7 | 0.527 | 1329.2 |
| Vegetables | 5026.4 | 0.651 | 3273.2 |
| Ruminant meat | -100.0 | 2.298 | -229.8 |
| Pork | 450.0 | 1.354 | 609.3 |
| Poultry meat | 300.0 | 1.228 | 368.3 |
| Milk | -2040.0 | 0.290 | -592.4 |
| Eggs | 50.0 | 1.011 | 50.6 |
| Fish | 1564.8 | 1.465 | 2292.7 |
| Carbohydrate feed | -16230.9 | 0.027 | -446.3 |
| Protein feed | -84247.2 | 0.059 | -4928.5 |
| Nonfood excl feed | 45717.6 | 1.181 | 53998.8 |
| **Total (= trade surplus)** | | | **49300.0** |

Since we will use the GTAP model to simulate the effects of shocks in China's trade volumes on world prices, we have to design a mapping matrix $T$ to convert Chinagro volumes $z$ into GTAP volumes $\tilde{z}$ : $\tilde{z} = Tz$ . Subsequently, after the GTAP simulations the resulting world price changes must be reconverted into Chinagro classification with the transpose matrix: $p = T^T \tilde{p}$ .

Establishing this mapping matrix is not straightforward, due to the different approach of Chinagro and GTAP concerning the classification of foreign commodities, as discussed already in the introduction. This difference leads to the question whether we should construct a separate mapping for imports and exports. Below, we adhere to the principle of commodity homogeneity

[7] Please note that in the Chinagro commodity list the oil and cake content of imported soybeans and oilseeds are classified as vegetable oils and protein feed, respectively (unless directly sold to households). Furthermore, agricultural commodities that are neither food nor feed (e.g. fibres, wool, wood) are included in non-agriculture.

of the Chinagro model (whether the commodity is imported and exported) and make just one mapping matrix, based on the dominant trade flow in 2004. Thus, we assume that this composition will also apply in case of regime switches in Chinagro model simulation.

The treatment of agricultural processing is another conceptual difference between Chinagro and GTAP. Chinagro focuses on the contents of the products, uses therefore the word ‘commodities’ and reduces processed commodities back to their origin by splitting them into their basic agricultural component (added to the raw commodity) and the additional processing value (considered as non-food). On the other hand, GTAP focuses on the production aspect, uses the word ‘sector’ and considers processed products as different from the raw ones. GTAP even integrates processed products of different origins (such as processed fruits, vegetables, fish and wheat) and different destinations (food and feed) into one sector. In deriving the mapping matrix we have to cope with this dissimilarity.

One of the consequences of this different approach to classification is that the $T$-matrix cannot be considered as a purely technical mapping since changing prices and income levels may lead to differences in the level of processing at which people consume their food, and hence also to differences in the composition of foreign trade. However, it will not be easy to express this price- and income-dependency empirically. Therefore, we keep the matrix constant.

Finally, the mapping matrix should reflect differences in the unit of measurement between Chinagro-commodities (expressed in physical units such as kg) and GTAP-sectors (expressed in constant dollars).

Version 7 of the GTAP database and modeling system will be used, having 2004 as baseyear. We take a sectoral aggregation of 27 sectors of which 20 agricultural ones. With respect to food/feed this classification is as disaggregate as possible (only paddy and milled rice together), in order to facilitate the mapping from Chinagro. With respect to nonfood, the classification is highly aggregate but still allows for some flexibility in specifying international scenarios. The GTAP classification is shown in Annex 2.

Since Chinagro has 17 commodities, the mapping matrix $T$ is 27 by 17. The numerical determination of $T$ is based on the correspondence between the estimated Chinagro net trade values (split into prices and quantities) and GTAP’s trade values, both for 2004. Annex 3 shows the structure of the matrix (with an ‘X’ for the potential non-zero elements) and the matrix itself, and briefly describes its derivation.

## 4. Single-commodity trade shocks

In this section, we describe the effects of single-commodity shocks in China's trade volumes on world prices as resulting from the GTAP-model. The shocks are specified in terms of the Chinagro commodities and then converted into GTAP sectors via the mapping matrix $T$. Subsequently, the effects on the world prices are obtained via simulation with the GTAP-model and converted back into Chinagro classification via the transposed matrix $T^T$. Below, we present the outcomes in terms of the Chinagro commodities, with $\Delta z$ representing the vector of shocks in net imports and $\Delta p^w$ the vector with resulting net increases in world prices.

Technically, the GTAP simulations are performed by replacing its China model component by exogenous trade flows. As mentioned earlier, we use the 27-sector GTAP classification listed in Annex 2. Furthermore, three regions are distinguished, viz. China, EU-27 and the Rest of the World.[8] The static 2004 model is applied (GTAP Version 7). The outcomes described here are obtained under standard international conditions and with standard elasticities.[9]

As mentioned earlier, GTAP has for each sector a full set of bilateral trade flows between countries or country groups, with at each border an export f.o.b. and import c.i.f. price. This structure is a complicating factor, not only for the derivation of the mapping matrix (discussed in the previous section) but also for the implementation of shocks and the use of the price outcomes. First, shocks in China's foreign trade must be distributed geographically before the GTAP simulation can be performed. It is done on the basis of observed international trade patterns. Secondly, GTAP can implement trade shocks either via the export side or via the import side. Thirdly, price changes come out separately for China's imports (itself a composite) and China's exports. All together, this leads to four different price effects (disregarding cross-commodity effects) that are illustrated in Table 4.1 for the case of milled rice.

The shock applied in Table 4.1 is 1000 ton, around 3% of the world trade volume in milled rice. The table shows four effects. The effect of the export shock on China's export price appears to be substantial causing an increase of .062 USD/kg, which is around 20% of the export price level (mentioned in Table 3.2). But the effect of the same shock on China's import price is extremely small. Apparently, on one hand, the parameters of the GTAP model lead to a rather strong segregation between 'China rice' and 'world rice', but on the other hand to quite some substitution within 'world rice'. The latter is also reflected in the effects of the import shock that are extremely small as well.

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[8] Initially, nine regions were distinguished, viz. Oceania, China, Rest of Asia excl. West Asia, North Africa plus West Asia, Sub-Saharan Africa, North America, Middle plus South America, EU-27 and Rest of Europe, but the price effects are rather similar.

[9] The standard trade elasticities of GTAP Version 7 are the same as those of Version 6 and can be found in Dimaranan et al (2005). For agricultural sectors the substitution elasticities between domestic and imported products range more or less from 2 to 4, whereas the substitution elasticities across import sources (countries) are exactly twice as large.

Table 4.1 GTAP price effects (in USD/kg) from a trade shock of 1000 ton in milled rice

| Commodity milled rice | Effect on China's export price | Effect on China's import price | Weighted effect on world price |
|---|---|---|---|
| Implementation of shock in GTAP via lower exports of China | 0.06207 | 0.00040 | 0.00261 |
| Implementation of shock in GTAP via higher imports of China | 0.00026 | 0.00021 | 0.00021 |

To approximate the effect at world market level, we calculate the weighted average of the effects on China's import and export price, using China's export share in world trade (from Table 3.1) as parameter for the weights.[10] The results are shown in the last column of Table 4.1. The effect of the export shock is then around 1% of the export price level, the effect of the import shock remains extremely low.

To see whether this difference between export and import shocks is characteristic for rice or applies generally, we compare the shocks for all commodities in Table 4.2. In this table, the price effects are weighted effects on world prices, calculated in the same way as in the last column of Table 4.1. The shocks in the table are close to 1% of world trade for all commodities (but lower if GTAP does not allow such a reduction in exports).[11] The table shows that the phenomenon of larger effects via export shocks than via import shocks applies to all commodities, albeit that the degree of the discrepancy varies. In the next section, we will take these differences into account when estimating the world price reaction functions.

In the last columns of the table the price shocks are translated into price flexibilities, defined as the relative increase in world price if China's exports are reduced (or China's imports are increased) by a volume equal to 1% of world trade.[12] These flexibilities give a first impression of the magnitudes of the relative effects caused by the shocks. However, they cannot be used to make comparisons across commodities since the outcomes of the flexibilities, in particular those via export reduction, appear to depend to a large extent on the size of the shock relative to the actual trade level. In this respect we should note that the flexibilities are calculated as average effect over the full range of the shock, as opposed to a marginal effect.

[10] The weighted average produced by GTAP itself seems very much biased towards the import price change and is, therefore, not used here.

[11] Export-reducing shocks are bounded from above by the export levels in GTAP's underlying 2004 data base, in particular by the most stringent of the export volumes of the GTAP sectors linked to the Chinagro commodity.

[12] Alternatively, we might call this measure 'trade shock elasticity of the world price' but we prefer the term 'price flexibility' since it is shorter and defined with respect to a 1% change in world trade instead of a 1% change in China trade.

Table 4.2 Effects of shocks in China's net imports on world prices, by Chinagro commodity: GTAP- implementation via exports versus GTAP-implementation via imports

| Commodity | Price level without shock, in USD per kg (food) or Mcal (feed) | Size of shock $(\Delta z)$, in 1000 mton (food) or 1000 mcal (feed) | Absolute price change $(\Delta p^w)$ when shock is implemented via lower exports | Absolute price change $(\Delta p^w)$ when shock is implemented via higher imports | Price flexibility when shock is implemented via lower exports | Price flexibility when shock is implemented via higher imports |
|---|---|---|---|---|---|---|
| Milled rice | 0.291 | 352.5 | 0.00067 | 0.00008 | 0.182 | 0.022 |
| Wheat flour | 0.204 | 569.7 | 0.00039 | 0.00010 | 0.397 | 0.105 |
| Maize | 0.122 | 1049.3 | 0.00082 | 0.00005 | 0.546 | 0.034 |
| Other staple food | 0.300 | 501.0 | 0.00124 | 0.00015 | 0.088 | 0.011 |
| Vegetable oil | 0.544 | 619.6 | 0.00112 | 0.00045 | 0.200 | 0.081 |
| Sugar | 0.233 | 110.7 | 0.00037 | 0.00002 | 0.614 | 0.031 |
| Fruits | 0.527 | 1000.0 | 0.00099 | 0.00056 | 0.110 | 0.062 |
| Vegetables | 0.651 | 810.9 | 0.00219 | 0.00074 | 0.216 | 0.073 |
| Ruminant meat | 2.298 | 31.1 | 0.00276 | 0.00046 | 0.379 | 0.063 |
| Pork | 1.354 | 53.0 | 0.00080 | 0.00023 | 0.086 | 0.024 |
| Poultry meat | 1.228 | 116.8 | 0.00097 | 0.00040 | 0.070 | 0.029 |
| Milk | 0.290 | 280.4 | 0.00028 | 0.00007 | 0.269 | 0.072 |
| Eggs | 1.011 | 100.0 | 0.00110 | 0.00022 | 0.018 | 0.004 |
| Fish | 1.465 | 500.0 | 0.00728 | 0.00248 | 0.492 | 0.167 |
| Carbohydrate feed | 0.027 | 2000.0 | 0.00001 | 4.E-6 | 0.016 | 0.006 |
| Protein feed | 0.059 | 4865.9 | 0.00013 | 0.00005 | 0.208 | 0.087 |

Notes:
1) the effects reported here are the effects on the own commodity (i.e. commodity that gets the shock)
2) the size of each shock is about 1% of the world trade volume (but lower if such a shock is not feasible in GTAP)
3) the flexibilities indicate the price change in % for shocks that equal 1% of world trade (hence, not 1% of China's trade)

Table 4.3 Full matrix of cross-price flexibilities: extension of Table 4.2 at same shock levels (implemented via reduced exports and represented column wise)

| Commodity affected | Net export shock (reduction) of around 1% of world trade | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Rice | Wheat | Maize | Oth.staple | Vegoil | Sugar | Fruits | Vegetable |
| Milled rice | 0.182 | 0.064 | 0.028 | 0.008 | 0.080 | 0.028 | 0.070 | 0.078 |
| Wheat flour | 0.028 | 0.397 | 0.031 | 0.009 | 0.091 | 0.032 | 0.080 | 0.089 |
| Maize | 0.028 | 0.072 | 0.546 | 0.035 | 0.091 | 0.032 | 0.080 | 0.088 |
| Other staple food | 0.026 | 0.067 | 0.217 | 0.088 | 0.377 | 0.029 | 0.075 | 0.083 |
| Vegetable oil | 0.025 | 0.066 | 0.029 | 0.016 | 0.200 | 0.030 | 0.075 | 0.082 |
| Sugar | 0.023 | 0.065 | 0.028 | 0.008 | 0.083 | 0.614 | 0.074 | 0.081 |
| Fruits | 0.023 | 0.066 | 0.029 | 0.008 | 0.083 | 0.030 | 0.110 | 0.126 |
| Vegetables | 0.024 | 0.066 | 0.029 | 0.009 | 0.084 | 0.030 | 0.167 | 0.216 |
| Ruminant meat | 0.024 | 0.068 | 0.030 | 0.009 | 0.086 | 0.031 | 0.078 | 0.086 |
| Pork | 0.025 | 0.069 | 0.030 | 0.009 | 0.088 | 0.032 | 0.080 | 0.087 |
| Poultry meat | 0.025 | 0.069 | 0.030 | 0.009 | 0.088 | 0.032 | 0.080 | 0.087 |
| Milk | 0.023 | 0.066 | 0.029 | 0.008 | 0.084 | 0.031 | 0.077 | 0.084 |
| Eggs | 0.026 | 0.071 | 0.032 | 0.009 | 0.090 | 0.032 | 0.084 | 0.092 |
| Fish | 0.022 | 0.064 | 0.028 | 0.008 | 0.081 | 0.030 | 0.096 | 0.099 |
| Carbohydrate feed | 0.025 | 0.067 | 0.178 | 0.016 | 0.084 | 0.165 | 0.113 | 0.143 |
| Protein feed | 0.025 | 0.064 | 0.028 | 0.022 | 0.167 | 0.028 | 0.071 | 0.079 |
| Nonfood excl.feed | 0.021 | 0.062 | 0.026 | 0.007 | 0.078 | 0.030 | 0.074 | 0.080 |
| | Rumin.mt | Pork | Poultry | Milk | Eggs | Fish | Chfeed | Protfeed |
| Milled rice | 0.057 | 0.024 | 0.028 | 0.056 | 0.004 | 0.111 | 0.006 | 0.067 |
| Wheat flour | 0.064 | 0.027 | 0.032 | 0.063 | 0.004 | 0.125 | 0.007 | 0.077 |
| Maize | 0.065 | 0.027 | 0.032 | 0.064 | 0.004 | 0.124 | 0.026 | 0.076 |
| Other staple food | 0.058 | 0.024 | 0.029 | 0.058 | 0.004 | 0.119 | 0.014 | 0.787 |
| Vegetable oil | 0.060 | 0.025 | 0.030 | 0.059 | 0.004 | 0.119 | 0.006 | 0.149 |
| Sugar | 0.059 | 0.025 | 0.030 | 0.060 | 0.004 | 0.119 | 0.007 | 0.068 |
| Fruits | 0.060 | 0.025 | 0.030 | 0.060 | 0.004 | 0.180 | 0.009 | 0.068 |
| Vegetables | 0.060 | 0.025 | 0.030 | 0.060 | 0.004 | 0.213 | 0.015 | 0.071 |
| Ruminant meat | 0.379 | 0.026 | 0.032 | 0.063 | 0.004 | 0.128 | 0.007 | 0.070 |
| Pork | 0.066 | 0.086 | 0.105 | 0.064 | 0.007 | 0.133 | 0.007 | 0.072 |
| Poultry meat | 0.066 | 0.057 | 0.070 | 0.064 | 0.006 | 0.132 | 0.007 | 0.071 |
| Milk | 0.062 | 0.026 | 0.031 | 0.269 | 0.004 | 0.128 | 0.007 | 0.067 |
| Eggs | 0.064 | 0.038 | 0.045 | 0.063 | 0.018 | 0.141 | 0.007 | 0.075 |
| Fish | 0.061 | 0.025 | 0.031 | 0.062 | 0.004 | 0.492 | 0.007 | 0.065 |
| Carbohydrate feed | 0.060 | 0.025 | 0.030 | 0.060 | 0.004 | 0.151 | 0.016 | 0.070 |
| Protein feed | 0.057 | 0.024 | 0.028 | 0.056 | 0.004 | 0.112 | 0.006 | 0.208 |
| Nonfood excl.feed | 0.060 | 0.025 | 0.030 | 0.061 | 0.004 | 0.124 | 0.006 | 0.059 |

The closer the shock brings export levels to zero, the more significant the flexibilities become. This follows from the functional specification in GTAP rather than from the characteristics of the commodities. By way of illustration, for wheat export shocks the flexibility (in absolute terms) is 0.862 for a downward shock of 712 thousand ton, 0.397 for the downward shock of 570 thousand ton in Table 4.2 and 0.262 for a downward shock of 142 thousand ton, whereas it is about 0.250 for a small upward shock and 0.144 for a large upward shock of 5 million ton. For other commodities similar patterns apply. Therefore, one cannot infer conclusions merely from a single, specific shock. Instead, the effects of a range of shocks must be simulated. Flexibilities can then be studied on the basis of estimated price-shock relationships. This will be the approach in the next section.

We conclude this section by presenting a full matrix of cross-commodity effects, Table 4.3, at the same shock levels as Table 4.2, implemented via export reduction. Two features emerge from this matrix. First, all cross-commodity effects have the same sign: all prices go up and down simultaneously. Secondly, the size of the cross-commodity flexibilities depends mainly on the commodity that gets the export shock: the impact on other commodities is remarkably similar. The only variation in the impact on other commodities seems to follow from the mapping matrix $T$ (and not from the outcomes of GTAP itself). In fact, if one considers different shock volumes, the cross-commodity flexibilities that are similar appear to be also insensitive to the size of the shock.

As a final remark, we should note that the impacts of the agricultural trade shocks on the nonfood prices in Table 4.3 are not negligible. Therefore, estimation of the world price reaction functions for Chinagro requires that relative price changes compared to non-food are used, i.e. $\Delta\left(p_k^w / \bar{p}_n^w\right)$ instead of $\Delta p_k^w$. Then, the own-commodity effects just become a bit smaller but the pattern of cross-commodity effects becomes drastically different, as one can observe by comparing the nonfood row in Table 4.3 with the other rows. In fact, many cross-commodity effects become significantly smaller, not to say that they almost disappear or even become negative. However, there are a number of cross-commodity effects that can definitely not be neglected, mainly as a direct consequence of the mapping matrix $T$. We mention the effects between ‘other staple food’’, protein feed and vegetable oil, the effects between vegetables and fruits, and the impact of several commodities (maize, sugar, vegetables, fish) on carbohydrate feed.

## 5. Single-commodity estimation

We start from the linear structure for the multi-commodity price reaction function derived in section 2:

$$p^w = \overline{p}_n^w (b + Az) \tag{5.1}$$

for a symmetric, positive definite $(n-1)\times(n-1)$ matrix A and positive vector $b \in \mathbb{R}^{n-1}$, in which $z \in \mathbb{R}^{n-1}$ the vector of net imports by China and $p^w \in \mathbb{R}^{n-1}$ the vector of world agricultural prices. A single-commodity specification with diagonal matrix A would give:

$$p_k^w / \overline{p}_n^w = b_k + a_k z_k \quad \text{for positive } a_k, b_k \tag{5.2}$$

However, on the basis of the different impacts of export shocks and import shocks in GTAP shown in the previous section, we opt for a modification with two branches, one for imports and one for exports, each with its own slope:

$$p_k^w / \overline{p}_n^w = \quad b_k + a_k^m z_k \quad \text{for } z_k \geq 0 \tag{5.3a}$$

$$b_k + a_k^e z_k \quad \text{for } z_k < 0 \tag{5.3b}$$

for positive slopes $a_k^m, a_k^e$ and intercept $b_k$. Distinguishing the two branches is meant to bridge the gap between the commodity homogeneity of Chinagro and the commodity heterogeneity of GTAP. Due to the common intercept of the branches, the function is continuous. The trade welfare function that leads to this specification is discussed in Annex 5.

Following the discussion of the previous section, we will also express the price observations in terms of the relative prices with respect to nonfood $p_k^w / \overline{p}_n^w$. Furthermore, we will generate samples with a sufficiently wide range of values of net imports $z_k$. More precisely, for each commodity we generate two samples of observations, one via shocks in GTAP exports and one via shocks in GTAP imports. Then, OLS on each sample gives the slopes $a_k^e$ and $a_k^m$, respectively. The intercept $b_k$ is taken from the dominant trade regime.[13]

For each commodity, we define a standard shock (of which the size is related to actual trade flows) and consider the range of -5 to +5 times this shock. In principle, these ten shocks are applied twice, once via China's export side in GTAP and once via China's import side. However, the downward shocks are bounded in GTAP since they cannot exceed -100% of actual trade levels. When such bounds are reached, alternative scaling methods are applied, leading to a total

[13] One could also estimate the three coefficients in a more refined way, i.e. jointly, but our focus here is more basic. The intercepts will be adjusted anyhow in the baseyear calibration of the Chinagro model. Our primary concern is to get insight in the size of the slopes and related flexibilities, in particular on the difference between the results from export shocks and those from import shocks.

of, say, 25 to 30 observations by commodity for the dominant trade regime and 15 to 20 observations for the other regime. Each observation consists of net import level $z_k$ and resulting relative price $p_k^w / \bar{p}_n^w$.

Figure 5.1 Observations and single-commodity estimation: rice via export shocks

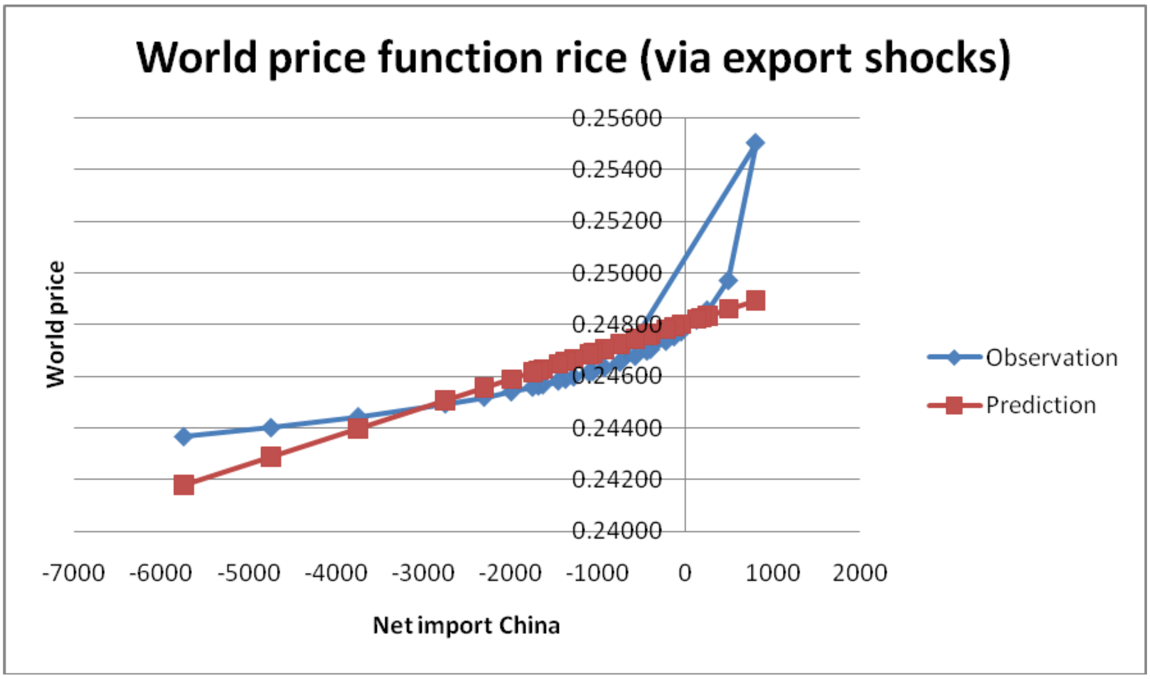
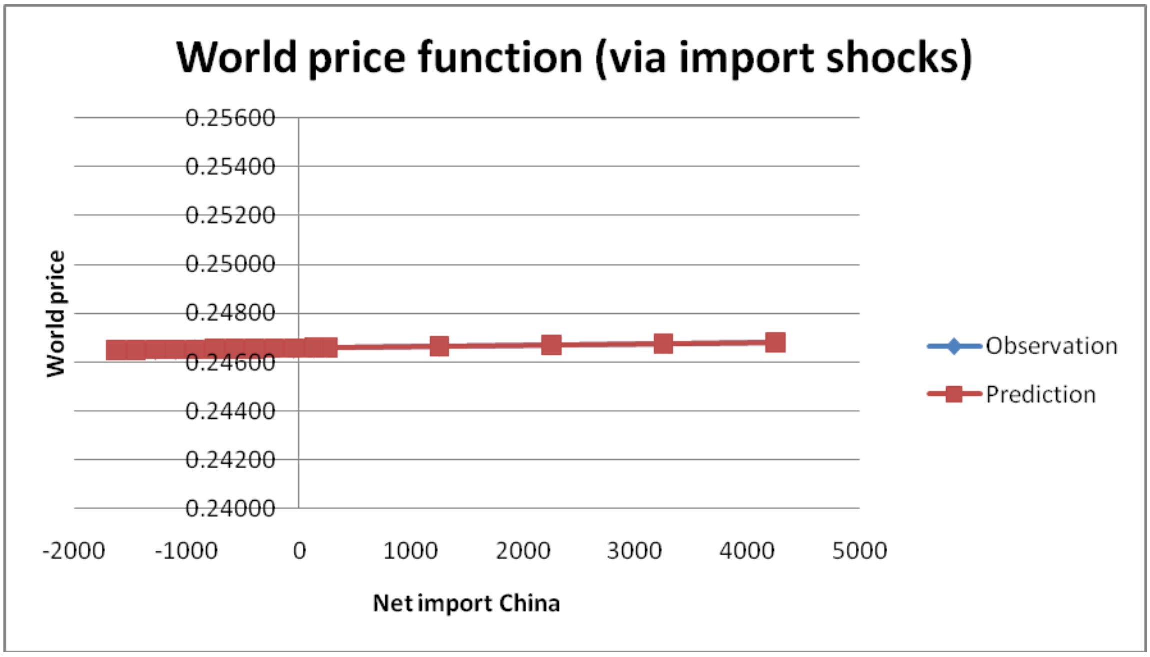



Figure 5.2 Observations and single-commodity estimation: rice via import shocks



As indicated already in the previous section, there is a clear difference between the observations obtained via the export shocks and those obtained via the import shocks. The reactions via the export side are not only larger but they are also increasing significantly when coming close to the maximal shock that can be analyzed. These patterns are illustrated in Figures 5.1 and 5.2 for rice. Figure 5.1 refers to export shocks, figure 5.2 to import shocks. Both figures have the same vertical scale, whereas the observations on the horizontal axis are measured as net imports. This may seem a bit illogical for the figure with export shocks but we prefer to present all results consistently in terms of net imports z.

The two figures are typical for most commodities. The estimated line in Figure 5.1 is clearly more steep than the line in Figure 5.2, which hardly rises. The latter more or less coincides with the observations (even prohibiting their visibility). Figure 5.1 also shows that the estimated line does not follow the steep increase of the observations towards the point where exports reach their upper bound.[14] In this respect, the range of the net import observations is sufficiently wide.

Table 5.1 Results of single-commodity OLS estimations (on the basis of export and import shocks in GTAP, respectively)

| | OLS via export shocks | | | OLS via import shocks | | |
|---|---|---|---|---|---|---|
| Commodity | Intercept | Slope | T-score slope | Intercept | Slope | T-score slope |
| Milled rice | 0.24806657 | 0.00000109 | 6.1 | 0.24657850 | 0.00000005 | 104.4 |
| Wheat flour | 0.17143870 | 0.00000016 | 5.6 | 0.17199861 | 0.00000007 | 6101.0 |
| Maize | 0.10553433 | 0.00000054 | 4.5 | 0.10307058 | 0.00000002 | 2737.5 |
| Other staple food | 0.25119514 | 0.00000204 | 6.6 | 0.25384654 | 0.00000006 | 123.2 |
| Vegetable oil | 0.45619345 | 0.00000057 | 7.3 | 0.45945615 | 0.00000013 | 91.4 |
| Sugar | 0.19658375 | 0.00000032 | 2.4 | 0.19687584 | 0.00000001 | 11.3 |
| Fruits | 0.44731212 | 0.00000029 | 21.2 | 0.44626712 | 4.70204E-10 | 0.8 |
| Vegetables | 0.56325816 | 0.00000181 | 11.1 | 0.55148951 | 0.00000003 | 20.9 |
| Ruminant meat | 1.94568706 | 0.00000865 | 2.1 | 1.94518792 | 0.00000086 | 45.7 |
| Pork | 1.15387073 | 0.00000968 | 7.9 | 1.14654615 | 0.00000029 | 128.8 |
| Poultry meat | 1.04188680 | 0.00000424 | 8.5 | 1.03938725 | 0.00000024 | 130.1 |
| Milk | 0.24561234 | 0.00000016 | 3.4 | 0.24584454 | 7.026345E-9 | 20.2 |
| Eggs | 0.85822182 | 0.00000889 | 11.4 | 0.85629299 | 0.00000038 | 476.1 |
| Fish | 1.26194459 | 0.00001111 | 10.9 | 1.24472842 | 0.00000271 | 318.2 |
| Carbohydrate feed | 0.02324607 | 2.727480E-9 | 31.5 | 0.02328058 | 1.04175E-10 | 78.7 |
| Protein feed | 0.04831986 | 0.00000002 | 8.3 | 0.04933848 | 2.357539E-9 | 30.0 |

Note: the estimates of the export branch are based on a sample of 25-30 trade shocks, and the estimates of the import branch on a sample of 15-20 trade shocks

[14] This upper bound is not precisely zero since trade flows are measured as net flows. With gross flows on the horizontal axis (and with perfect matching of the 2004 data of Chinagro and GTAP) the bound would be zero.

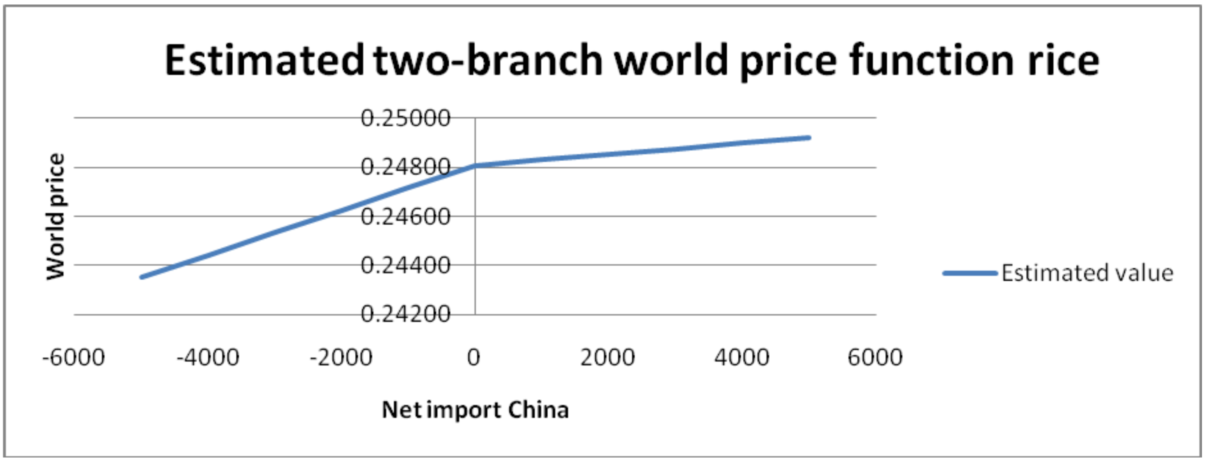
Table 5.1 presents the estimation results for all commodities. Statistically, the outcomes are very significant.[15] However, regarding the levels of the coefficients two implausible features stand out immediately, viz. the very low level of the slopes of carbohydrate feed and the huge differences between export and import slopes for most commodities. Therefore, we apply two ad-hoc adjustment rules. First, the slopes of carbohydrate feed are doubled, leaving them still very low but at least a bit closer to those of other feeds. Secondly, the gap between export and import slopes is reduced by imposing a maximal ratio of 4 while keeping the sum of the two slopes the same. The results are shown in table 5.2 and graphically illustrated for rice in Figure 5.3.

Table 5.2 Coefficients of two-branch single-commodity world price reaction functions (after adjustment)

| Commodity | Intercept | Slope export branch | Slope import branch |
|---|---|---|---|
| Milled rice | 0.24806657 | 0.00000091 | 0.00000023 |
| Wheat flour | 0.17199861 | 0.00000016 | 0.00000007 |
| Maize | 0.10553433 | 0.00000045 | 0.00000011 |
| Other staple food | 0.25384654 | 0.00000168 | 0.00000042 |
| Vegetable oil | 0.45945615 | 0.00000056 | 0.00000014 |
| Sugar | 0.19687584 | 0.00000027 | 0.00000007 |
| Fruits | 0.44731212 | 0.00000024 | 0.00000006 |
| Vegetables | 0.56325816 | 0.00000147 | 0.00000037 |
| Ruminant meat | 1.94518792 | 0.00000761 | 0.00000190 |
| Pork | 1.15387073 | 0.00000798 | 0.00000200 |
| Poultry meat | 1.04188680 | 0.00000358 | 0.00000089 |
| Milk | 0.24584454 | 0.00000013 | 0.00000003 |
| Eggs | 0.85822182 | 0.00000741 | 0.00000185 |
| Fish | 1.26194459 | 0.00001106 | 0.00000276 |
| Carbohydrate feed | 0.02328058 | 4.530648E-9 | 1.132662E-9 |
| Protein feed | 0.04933848 | 0.00000001 | 3.482935E-9 |

[15] The t-scores of the intercepts are very large and, hence, there is no need to report them. On the whole, there is only one insignificant coefficient, viz. the slope of the fruit price equation obtained via the import side.

Figure 5.3 Two-branch world price function for rice




The price flexibilities implied by these outcome are shown in Table 5.3, at different trade levels. Just as the measures in Table 4.2 they refer to the impact of changes in China's net import volumes that equal 1% of world trade (and not 1% of China's trade), but here they are derived analytically as marginal effect from the estimated equations instead of calculated as average effects for a specific shock. Furthermore, the equations are now expressed in terms of relative price changes compared to nonfood.

Table 5.3 Price flexibilities on the basis of the two-branch world price functions, at different import and export levels

| | With respect to exports, at export level: | | | With respect to imports, at import level: | | |
|---|---|---|---|---|---|---|
| Commodity | 1000 | 2000 | 5000 | 1000 | 2000 | 5000 |
| Milled rice | 0.104 | 0.104 | 0.105 | 0.026 | 0.026 | 0.026 |
| Wheat flour | 0.113 | 0.113 | 0.113 | 0.049 | 0.049 | 0.049 |
| Maize | 0.363 | 0.365 | 0.370 | 0.090 | 0.090 | 0.090 |
| Other staple food | 0.071 | 0.072 | 0.073 | 0.018 | 0.018 | 0.018 |
| Vegetable oil | 0.073 | 0.073 | 0.074 | 0.018 | 0.018 | 0.018 |
| Sugar | 0.058 | 0.058 | 0.058 | 0.015 | 0.015 | 0.014 |
| Fruits | 0.031 | 0.031 | 0.031 | 0.008 | 0.008 | 0.008 |
| Vegetables | 0.136 | 0.136 | 0.137 | 0.034 | 0.034 | 0.034 |
| Ruminant meat | 0.039 | 0.039 | 0.039 | 0.010 | 0.010 | 0.010 |
| Pork | 0.054 | 0.054 | 0.055 | 0.013 | 0.013 | 0.013 |
| Poultry meat | 0.035 | 0.036 | 0.036 | 0.009 | 0.009 | 0.009 |
| Milk | 0.042 | 0.042 | 0.042 | 0.011 | 0.011 | 0.011 |
| Eggs | 0.014 | 0.014 | 0.015 | 0.004 | 0.004 | 0.004 |
| Fish | 0.438 | 0.441 | 0.454 | 0.108 | 0.108 | 0.107 |
| Carbohydrate feed | 0.018 | 0.018 | 0.018 | 0.004 | 0.004 | 0.004 |
| Protein feed | 0.128 | 0.128 | 0.128 | 0.032 | 0.032 | 0.032 |

Note: The flexibilities are defined similarly to Table 4.2, viz. as the increase of the world price (in %) if China's exports decrease or China's imports increase with 1% of world trade, and refer to the own commodity.

From Table 5.3 we observe that the flexibilities calculated on the basis of the linearized segments are quite stable, i.e. hardly sensitive to the point in which they are calculated. However, the differences between the flexibilities on the import and export branch are large. Not surprisingly, given the ad-hoc adjustment rule specified above, many of the flexibilities on the export branch are about 4 times as high as the flexibilities on the import branch.[16]

It is hard to come with a direct assessment of the levels of the flexibilities along the export branches, but it is clear that the differences across the commodities are significant. The maize flexibility of 0.36 appears to be high compared to the other grains, but at first sight the levels for wheat and rice of around 0.10 cannot be refuted either. For animal products, the situation is different. The fish flexibility of 0.44 is quite substantial (even the highest of all commodities) but the flexibilities of meat, eggs and dairy are implausibly low, at levels of 0.02 to 0.05. Also the flexibility of carbohydrate feed of 0.02 seems too low, in spite of its ad-hoc doubling, especially compared to the flexibilities of respectively 0.13 and 0.36 for protein feeds and maize, the other feed commodities.

Concerning the estimation of these export flexibilities, one may argue (as we did above) that the sample is indeed wide enough to keep the impact of the steep part of the set of observations limited. However, the linearization may also reduce the outcomes a bit too much in the sense that too many observations are on the flat part of the set of observations. In terms of the graph of Figure 5.1, we could have shifted the sample of observations a bit more to the right, leading to a higher slope and, hence, a higher flexibility.

In section 7, we will further discuss the plausibility of the price flexibilities and outline the actual use of the single-commodity world price equations in the Chinagro model. However, first we will consider the impact of multi-commodity shocks as opposed to single-commodity shocks. This comparison brings the intensity of cross-commodity price effects clearly to the fore. The single-commodity estimations of this section ignore these effects, although we know from Table 4.3 that not all of them are negligible.

[16] Compared to the (rather constant) flexibilities on the basis of import shocks reported in the previous section, the current flexibilities of the import branch are lower since they refer now to changes in relative world prices (relative to nonfood). This effect dominates the increase by the ad-hoc ‘factor 4’ adjustment rule.

## 6. Multiple shocks instead of single shocks

So far, we studied merely the impact of single-commodity trade shocks and, in particular, their impact on the own commodity. In this section we turn to multi-commodity shocks and address the question whether they strengthen or weaken the impact of single shocks on the own commodity. Table 6.1 illustrates the question for the case of rice, wheat and maize. For rice it shows the effects on the world rice price of several shocks with as common element a change in China's rice trade of 1000 ton. Similar effects are shown for wheat and maize.

Table 6.1 Net increases in world grain prices: effects of multiple versus single shocks

| | 1000 ton more exports : implementation via exports in GTAP | | 1000 ton more imports: implementation via imports in GTAP | |
|---|---|---|---|---|
| *Net increase in rice price* | | | | |
| | Absolute price | Relative price | Absolute price | Relative price |
| Single rice shock | -0.00136 | -0.000967 | 0.00021 | 0.000051 |
| All grain shock | -0.00172 | -0.000974 | 0.00047 | 0.000066 |
| All staple shock | -0.00200 | -0.000994 | 0.00070 | 0.000073 |
| All crop shock | -0.00433 | -0.000962 | 0.00204 | 0.000059 |
| All agriculture shock | -0.00693 | -0.000834 | 0.00295 | 0.000017 |
| *Net increase in wheat price* | | | | |
| | Absolute price | Relative price | Absolute price | Relative price |
| Single wheat shock | -0.00033 | -0.000187 | 0.00018 | 0.000072 |
| All grain shock | -0.00068 | -0.000240 | 0.00040 | 0.000105 |
| All staple shock | -0.00090 | -0.000274 | 0.00058 | 0.000129 |
| All crop shock | -0.00273 | -0.000412 | 0.00166 | 0.000241 |
| All agriculture shock | -0.00471 | -0.000466 | 0.00241 | 0.000304 |
| *Net increase in maize price* | | | | |
| | Absolute price | Relative price | Absolute price | Relative price |
| Single maize shock | -0.00094 | -0.000734 | 0.00009 | 0.000039 |
| All grain shock | -0.00114 | -0.000764 | 0.00023 | 0.000057 |
| All staple shock | -0.00144 | -0.000926 | 0.00035 | 0.000079 |
| All crop shock | -0.00251 | -0.001001 | 0.00099 | 0.000143 |
| All agriculture shock | -0.00369 | -0.001032 | 0.00144 | 0.000183 |

Table 6.1 shows that the absolute effects of single commodity shocks are consistently increased when other shocks are added, often even substantially. However, more important are the relative effects, i.e. the increase in the relative price compared to nonfood. In this respect, one can observe differences across the commodities. While for wheat the relative price effects increase significantly when other shocks are added, the increases for maize (in case of exports) are more moderate while for rice one even observes a decline when the shocks are extended to all crops or

all agricultural commodities, indicating that the additional nonfood price increase is larger than the additional price increase of rice itself.

However, when considering the same effects also for other commodities than grains, it turns out that the dominant picture is one of increasing relative price effects. Hence, rice is to some extent an exception. Indeed, rice is the only commodity for which the change in its relative price is larger for the single shock than for the 'all-commodity' shock, although also for a few other commodities (vegetable oil, protein feed) not every enlargement of the shock means an enlargement of the increase in the relative price. Table 6.2 provides more evidence by showing a similar chain of effects as in Table 6.1, this time for three selected commodities, viz. vegetables, pork and carbohydrate feed. Especially, the outcomes for carbohydrate feed are striking since it appears that the very low effects observed earlier for single shocks become much larger when other shocks are added.

Table 6.2 Net increases in world prices of selected commodities (other than grains): effects of multiple versus single shocks

| | More exports:* implementation via exports in GTAP | | More imports:* implementation via imports in GTAP | |
|---|---|---|---|---|
| *Net increase in price of vegetables* | | | | |
| | Absolute price | Relative price | Absolute price | Relative price |
| Single vegetable shock | -0.00510 | -0.002500 | 0.00172 | 0.000059 |
| All cashcrop shock | -0.00714 | -0.003207 | 0.00245 | 0.000071 |
| All crop shock | -0.01133 | -0.003554 | 0.00465 | 0.000213 |
| All agriculture shock | -0.01791 | -0.003952 | 0.00684 | 0.000249 |
| *Net increase in price of pork* | | | | |
| | Absolute price | Relative price | Absolute price | Relative price |
| Single pork shock | -0.00669 | -0.003754 | 0.00188 | 0.000154 |
| All meat shock | -0.01442 | -0.006505 | 0.00500 | 0.000386 |
| All animal products shock | -0.01780 | -0.006847 | 0.00653 | 0.000486 |
| All agriculture shock | -0.03706 | -0.008071 | 0.01510 | 0.001250 |
| *Net increase in price of carbohydrate feed* | | | | |
| | Absolute price | Relative price | Absolute price | Relative price |
| Single shock in carbohydrate feed | -0.00001 | -0.000005 | 4E-6 | 2E-7 |
| All feed shock | -0.00010 | -0.000055 | 0.00004 | 0.000004 |
| All crop shock | -0.00046 | -0.000136 | 0.00020 | 0.000012 |
| All agriculture shock | -0.00072 | -0.000139 | 0.00029 | 0.000014 |

*) 2000 ton for vegetables, 500 ton for pork, 2000 Gcal for carbohydrate feed

Tables 6.1 and 6.2 show that simultaneous shocks on several commodities may reinforce each other considerably. It even shows that these reinforcements may be larger for implementation via the import side than via the export side. Earlier already, from Table 4.3, we noticed that there are a number of cross-commodity effects that cannot be neglected, mainly as a direct consequence of the mapping matrix $T$. Altogether, this evidence confirms that we should indeed not restrict ourselves to estimation of single-commodity equations. Instead, we should to proceed to multi-commodity estimation.

However, as indicated already in the introduction we confine ourselves in this report to estimation of single-commodity equations, leaving estimation of cross-commodity effects to a subsequent stage. Preparing for that stage, we conclude this section by outlining already how the multi-commodity estimation could proceed.

As shown in Annex 5, the generalized version of the single-commodity two-branch linear equations (5.3) is:

$$p^w \Big/ \bar{p}_n^w = b - A^e \, max(-z,0) + A^m \, max(z,0) \qquad (6.1)$$

with $b \in \mathbb{R}^{n-1}$ a positive vector and the $(n-1)\times(n-1)$ matrices $A^e$ and $A^m$ symmetric and strictly positive definite, and where the max-operators apply to each element of the $(n-1)$ dimensional vectors. The sample for estimation can be constructed by (1) randomly drawing from the $2^{n-1}$ different yes-no combinations of vector z, and (2) applying scaling procedures to each of these combinations in a similar way as done for single-commodity shocks. Again, these shocks can be implemented in GTAP either via the export or via the import side. Step (1) should guarantee sufficient representation of possible yes-no combinations, whereas step (2) should ensure adequate coverage along each of these directions while obeying the upper bounds on shocks set by the GTAP-model.[17]

Analogous to the single-commodity case, we can use the export shocks to estimate matrix $A^e$ and the import shocks to estimate matrix $A^m$, arriving again at a procedure in three steps:

- use export shocks as data sample to estimate a linear system with intercept and matrix $A^e$
- use import shocks as data sample to estimate a linear system with intercept and matrix $A^m$
- determine vector b by taking for each commodity a common intercept, viz. the one from the dominating branch.

Estimation of each of the linear systems should be based on a simultaneous estimation method while ensuring symmetry and positive definiteness of the matrix. Further details are provided in Annex 6, applying an extended version of the method of Generalized Least Squares (GLS).

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[17] Actually, we have prepared already a random sample based on 2000 drawings in step (1), which amounts to about 3% of the total number of possible directions ($2^{n-1}$ = 65536 for n=17), and 5 to 6 shocks along each direction in step (2), for exports respectively imports.

## 7. Application and model impact

Here, we discuss how the two-branch world price reaction functions of section 5 are actually applied in the Chinagro model. Earlier, we noted already that some of the price flexibilities seem implausibly low, in particular those of meat, eggs, dairy and carbohydrate feed. However, it is not easy to make a comparison of the flexibilities purely on the basis of a priori grounds. Therefore, we will also make an effort to infer additional evidence from the literature.

Differences across flexibilities can be attributed the degree of homogeneity of the commodity, the storage life of the commodity and expected supply-demand tensions. The size of the world market may be added as fourth discerning factor but in this case it does not apply due to our definition of the concept of flexibility (which is already expressed with respect to the level of world trade). The more homogeneous the commodity is, the smoother the substitution for closely related products and hence the lower the price reaction will be. Also a long storage life will lead to reduced price reactions. On the other hand, expected increases of scarcity will cause stronger price reactions.

On the basis of these considerations, one can explain why the flexibility of maize is higher than the flexibility of wheat and rice (market tensions due to biofuel demand) and why fish is the commodity with the highest flexibility (very heterogeneous commodity and limited storage options). Also the relatively high flexibility of vegetables can be attributed to the heterogeneity of trade in this commodity. Yet, not all differences can be explained since for similar reasons one would expect relatively high flexibilities of fruits (heterogeneity, storage options), meat (heterogeneity) and carbohydrate feed (biofuel use) whereas the results show differently.

To obtain evidence from the literature, we consider simulation outcomes of three studies with worldwide general or partial equilibrium models. OECD (2007) presents simulations of the effect of worldwide GDP increases on agricultural world market prices, as part of the documentation of the AGLINK-COSIMO model jointly operated by OECD and FAO. Rosegrant (2001) shows the outcomes of simulations of optimistic and pessimistic global scenarios, obtained with IFPRI's IMPACT model. Carriquiry et al (2010) outline the world market impact of high biofuel use in the European Union on the basis of the FAPRI modeling system. Since the experiments in these studies are not directly cast in terms of world trade shocks (let alone Chinese trade shocks), we have to translate them into such shocks. More in particular, we have to express them as original shocks, i.e. the shocks before world market equilibrium is restored.

The AGLINK-COSIMO documentation shows the medium-term impact of a simultaneous 1% increase in GDP in all countries on worldwide consumption, production and market prices for some 10 relevant commodities. When one is willing to make an assumption about the initial shocks on consumption (say, 50% higher than the ultimately resulting equilibrium outcomes) and subsequently translates them into shocks on world imports (by applying the FAO shares of world trade in world consumption), one may interpret the world market price changes as the changes that are required to restore equilibrium after the initial trade shocks. These data can then be used to calculate the price flexibility related to the trade shock.

Table 7.1 Calculation of price flexibilities related to world trade shocks on the basis of AGLINK-COSIMO simulations*

| Commodity | World import shock (%) | World price increase (%) | Price flexibility |
|---|---|---|---|
| Rice | 1.69 | 0.38 | 0.23 |
| Wheat | 0.90 | 0.36 | 0.40 |
| Coarse grain | 1.80 | 0.70 | 0.39 |
| Oilseed | 1.65 | 0.43 | 0.26 |
| Oilseed meal | 1.15 | 0.57 | 0.50 |
| Vegetable oils | 0.87 | 0.72 | 0.83 |
| Beef | 4.60 | 0.43 | 0.09 |
| Pork | 3.88 | 0.65 | 0.17 |
| Cheese | 1.86 | 0.68 | 0.37 |
| Butter | 2.91 | 0.49 | 0.17 |
| Whole milk powder | 0.73 | 0.47 | 0.65 |

* assuming a 50% higher initial consumption shock than the medium-term effect reported in OECD(2007)

Figure 7.1 shows the resulting price flexibilities, assuming that the initial consumption shocks are 50% higher than the equilibrium ones, for each commodity. These flexibilities are clearly higher than the ones reported in Table 5.3 on the basis of the two-branch world price functions, even higher than those of the export branch. In fact, if one considers the 50% upward increase of the consumption shock on the high side, the import shocks in Table 7.1 can be seen as an upper bound and, consequently, the price flexibilities as a lower bound. Yet, also these results raise some questions. In particular, one might wonder why beef and pork are so low and milk powder is so high.

Similar calculations can be made for (aggregate) cereals on the basis of the outcomes of the optimistic and pessimistic scenarios simulated with IFPRI's IMPACT model. Using again a 50% increase to determine the initial trade shock, price flexibilities of 0.30 and 0.40 result for the optimistic and pessimistic scenario, respectively. The biofuel simulations with the FAPRI modeling system are of a somewhat different kind. They can directly be translated in EU import shocks that have to be cleared on the world markets. For wheat an additional EU import of about 65 thousand ton (0.06% of world trade) leads to 0.02% increase of the world wheat price, suggesting a wheat price flexibility of 0.33. In another simulation, the additional EU import of rapeseed oil is about 155 thousand ton (8.5% of world trade), but here the text is not explicit about the world price increases of rapeseed oil itself. From the indirect effect of around 1% on the world price of other oils one may assume an increase of the rapeseed oil price of at least 1.5%, implying a price flexibility of at least 0.18.

Although these outcomes are based on additional assumptions (compared to the original sources) and not free of inconsistencies themselves, the results uniformly point to stronger world price reactions than the GTAP-based flexibilities indicate. In this sense, the references to the literature support our a priori view that the slope coefficients of the two-branch functions are in general too low. Therefore, upward adjustments of the outcomes of section 5 seem appropriate. To some extent, these upward adjustments may also be justified from the estimation process itself, viz. reflecting (a) use of a narrower sample, or (b) compensation for missing multiple shock effects, or (c) outcomes of a GTAP version with lower substitution elasticities. Concerning the last point, experiments show that a 50% reduction of the standard GTAP substitution elasticities leads to significantly higher slopes of the export branch, for many commodities even twice as high.[18]

Based on these considerations and the additional evidence we raised the slopes of the export branch significantly and those of the import branch even more.[19] Although the adjustments are rather subjective, by their very nature, we feel that they bring the resulting functions closer to the literature and to the a priori beliefs about differences across commodities.

When the resulting two-branch function is applied in the Chinagro model, its intercept is recalculated by calibrating the function to the observed import and export prices and net import volumes of the model's baseyear data set. In this process an assumption is made for the values of price margins $\tau_k^w$ in equation (2.5).[20] The calibration procedure leads to moderate changes in the intercepts, mainly capturing the difference in price level between the estimation year (2004) and the Chinagro baseyear (2005). In performing model simulations over the period 2005-2030, the scenario trend of world price developments is applied to both the intercept and the slopes of the two-branch world price function, hence not only to the intercept.

The impact of the world price functions on the model outcomes is significant. In the previous specification the rigidity of foreign trade prices caused at the same time significant inflexibility in domestic prices. In the new specification, however, reduced net demand of China always leads to lower domestic prices (or the opposite), even when the trade regime does not change. Hence, the new Chinagro model is more responsive than the earlier version. For instance, in the baseline scenario of the updated Chinagro model, the increased imports of maize and protein feed in the period 2005-2030 lead to increases of around 5% in the foreign trade prices of these

[18] However, surprisingly, the effects via the import side go down somewhat.

[19] In general, we raised the slopes of the export branch by a factor two and those of the import branch by a factor four (for rice, vegetables, fruits, poultry, milk, carbohydrate feed and protein feed even more, for fish less).

[20] Furthermore, we allow for (exogenous) committed trade volumes $\overline{z}_k^c$, hence equations (5.3a) and (5.3b) are specified in terms of $z_k - \overline{z}_k^c$ instead of $z_k$ (at the same slopes).

commodities. Furthermore, lower economic growth may now easily lead to decreases of 5% or more in the farmgate prices of major grains, meat and milk due to reduced consumer demand (Keyzer and Van Veen, 2010).

Finally, as explained in the introduction, different international conditions call for different world price reaction functions. Ideally, we should derive these functions from separate GTAP-based estimations. To this end, we did explore two alternative GTAP simulations, one under generally tight international market conditions and one with additional biofuel demand worldwide. However, the outcomes appear to be only marginally different from the standard outcomes, if different at all. Therefore, we cannot really use them in the specification of alternative Chinagro scenarios. Instead, we will have to follow an ad-hoc approach when adjusting the world price functions to other international situations.

Similar remarks apply to the time-dependency of the world trade price functions. We might consider using a multi-period application of GTAP (intrinsically a static model that can give dynamic results by a series of successive applications with updates of exogenous variables) and including time as explanatory variable in the price functions. However, given the experiences so far, we confine ourselves to static outcomes that are made time-dependent in the specification of the Chinagro scenario itself, in particular (as mentioned above) by linking intercept and slopes to exogenous world price trends.

## 8. Evaluation

In this report we have estimated functions that describe the reactions of agricultural world market prices to changes in China's imports or exports. These estimations are based on samples of observations generated by simulations with version 7 of the GTAP modeling system and reclassified into the commodity list of the Chinagro model. The resulting functions have been used to extend the Chinagro welfare model with international agricultural market responses. So far, we focused on single-commodity equations estimated via OLS. The main conclusions are as follows:

1) The world price reaction functions had better be cast in a formulation with two branches, one for exports and one for imports, since the reactions via export shocks in GTAP are much stronger than the reactions via import shocks.
2) A linear approximation of GTAP-reactions is rather sensitive to the width of the sample, in particular to the frequency of observations with minor imports or exports.
3) For samples with a moderately wide coverage the GTAP-based price reactions, even those via the export side, are rather low compared to what would be suggested by evidence from the literature, whereas differences across commodities cannot always be explained on a priori grounds.
4) A closer look at available studies in the literature provides enough justification to raise the GTAP-based reaction coefficients upwards and to limit the differences between export and import side.
5) Extending the Chinagro model with the (adjusted) two-branch world price reaction functions has a significant impact on the outcomes of the model simulations of China's agricultural economy in the next decades since prices become more responsive and the pressure on international markets is better visible.
6) Attempts to estimate separate reaction functions for specific international conditions fail since the GTAP outcomes are only marginally different from those under standard international conditions.
7) Simulations with multi-commodity shocks in GTAP (as well as analysis of cross-commodity effects of single-commodity shocks) show that one should preferably estimate a system of multi-commodity equations instead of single-commodity equations but also these refined estimations will require ad-hoc adjustments similar to those applied currently.

Based on these conclusions, we do indeed consider proceeding to a second stage in which a system of multi-commodity equations will be estimated. In fact, preparations concerning data and method have already been made. However, again we will be faced by GTAP-outcomes that do not sufficiently represent the characteristics of specific commodities. Hence, the basic question will again be how to adjust in a justifiable manner the formal GTAP-based estimation results, with the purpose of bringing the outcomes closer to the evidence from the literature.

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## Annex 1. Chinagro commodity-classification

| <u>Chinagro</u> | <u>Unit</u> |
|---|---|
| 1. Rice | (thousand metric ton milled) |
| 2. Wheat | (thousand metric ton flour) |
| 3. Maize | (thousand metric ton) |
| 4. Other staple food | (thousand metric ton soybean equivalent) |
| 5. Vegetable oil | (thousand metric ton) |
| 6. Sugar | (thousand metric ton) |
| 7. Fruits | (thousand metric ton) |
| 8. Vegetables | (thousand metric ton) |
| 9. Ruminant meat | (thousand metric ton) |
| 10. Pork | (thousand metric ton) |
| 11. Poultry meat | (thousand metric ton) |
| 12. Milk | (thousand metric ton) |
| 13. Eggs | (thousand metric ton) |
| 14. Fish | (thousand metric ton) |
| 15. Nonfood excl feed | (ten million constant 1997 Yuan) |
| 16. Carbohydrate feed | (thousand gigacal) |
| 17. Protein feed | (thousand gigacal) |

Remarks:

- Other staple food covers minor grains, roots and tubers, as well as soybeans and peanuts directly consumed by the household
- Imported soybeans are largely allocated to their processing products, viz. vegetable oil, protein feed and nonfood (only a small part considered as ‘other staple food’)
- Melons are included in vegetables (not in fruits)
- Animal fats, coffee, tea, spices, cocoa, beverages, sauces and juices are included in nonfood
- Carbohydrate feed consists of cassava, citrus or melon peel, prepared cereal straw, fodder roots and crops, molasses, food processing residuals as well as minor grains and tubers directly used as feed
- Protein feed consists of cereal bran, fish meal, meat meal, oilseed cake and oilseed meal and flour
- Local feeds such as grass, straw and other crop residuals are also represented in the Chinagro model but not as a tradable commodity
- Processed commodities are partly included in the basic agricultural commodity (viz. the ‘raw’ value) and partly in non-food (viz. the processing value)

## Annex 2. GTAP-sector classification used (27 sectors)

| No. | Code | Description | Comments |
|---|---|---|---|
| 1 | Ric | Rice | Paddy and milled rice |
| 2 | Wht | Wheat | Grain (excl. flour) |
| 3 | Gro | Other cereals | Grain (excl. flour) |
| 4 | V_f | Vegetables, fruits, nuts | Fresh or dried; includes root crops |
| 5 | Osd | Oil seeds | |
| 6 | C_b | Sugar cane and beet | |
| 7 | Pfb | Plant-based fibers | |
| 8 | Ocr | Other crops | Spices, coffee, tea, cocoa, plants, flowers, bulbs, fodder |
| 9 | Ctl | Cattle, sheep, goats, horses | Live animals |
| 10 | Oap | Other animal products | Live pigs and poultry; hides, skins, bones, guts; eggs |
| 11 | Rmk | Raw milk | |
| 12 | Wol | Wool, silk-worm cocoons | |
| 13 | Cmt | Bovine, ovine and horse meat | Fresh, chilled or frozen; includes offals and fats |
| 14 | Omt | Other meat products | Pork, poultry meat, game meat, rabbit meat (fresh, chilled, frozen, salted, dried or smoked); sausages and other meat preparations; flours and meals of meat and offal |
| 15 | Vol | Vegetable oils and fats | Includes also oil cakes |
| 16 | Mil | Dairy products | |
| 17 | Sgr | Sugar | |
| 18 | Ofd | Other food products | Cereal flour and cereal preparations; starch; prepared and preserved vegetables, fruits, nuts and fish; cocoa butter, chocolate, sugar confectionary; soup and sauces; feed such as fishmeal, bran, beetpulp, bagasse, citrus peels and other food processing residuals |
| 19 | B_t | Beverages and tobacco | |
| 20 | Fsh | Fishing | Fresh, chilled or live fish |
| 21 | Ext | Mining and Extraction | |
| 22 | Txt | Textiles and Clothing | |
| 23 | Lmf | Light Manufacturing | |
| 24 | Hmf | Heavy Manufacturing | |
| 25 | Utl | Utilities and Construction | |
| 26 | trc | Transport and Communication | |
| 27 | osr | Other Services | |

## Annex 3. Mapping from Chinagro-commodity to GTAP-sector

First, the (potentially) non-zero elements of the mapping matrix are identified, based on the definitions of commodities and sectors given in Annex 1 and Annex 2. These elements are indicated in Table A3.1

Table A3.1: Mapping matrix from Chinagro to CCAP: zero versus non-zero

| *Chinagro* *Gtap* | Rice | Wheat | Maize | Othstaple | Veg.oil | Sugar | Fruits | Vegetab | Rummeat | Pork | Poulmeat | Milk | Eggs | Fish | Chfeed | Protfeed | Nonfood |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ric | X | | | | | | | | | | | | | | | | |
| Wht | | X | | | | | | | | | | | | | | | |
| Gro | | | X | X | | | | | | | | | | | X | | |
| V_f | | | | X | | | X | X | | | | | | | X | | |
| Osd | | | | X | X | | | | | | | | | | | X | X |
| C_b | | | | | | X | | | | | | | | | | | |
| Pfb | | | | | | | | | | | | | | | | | X |
| Ocr | | | | | | | | | | | | | | | X | | X |
| Ctl | | | | | | | | | X | | | | | | | | X |
| Oap | | | | | | | | | | X | X | | X | | | | X |
| Rmk | | | | | | | | | | | | X | | | | | |
| Wol | | | | | | | | | | | | | | | | | X |
| Cmt | | | | | | | | | X | | | | | | | | X |
| Omt | | | | | | | | | | X | X | | | | | X | X |
| Vol | | | | | X | | | | | | | | | | | X | |
| Mil | | | | | | | | | | | | X | | | | | |
| Sgr | | | | | | X | | | | | | | | | X | | |
| Ofd | | X | | X | | | X | X | | | | | X | X | X | X | X |
| B_t | | | | | | | | | | | | | | | | | X |
| Fsh | | | | | | | | | | | | | | X | | | |
| Ext | | | | | | | | | | | | | | | | | X |
| Txt | | | | | | | | | | | | | | | | | X |
| Lmf | | | | | | | | | | | | | | | | | X |
| Hmf | | | | | | | | | | | | | | | | | X |
| Utl | | | | | | | | | | | | | | | | | X |
| Trc | | | | | | | | | | | | | | | | | X |
| Osr | | | | | | | | | | | | | | | | | X |

PM. X = (potential) non-zero

The coefficients of this matrix are derived as follows:

First, a two-dimensional matrix of net trade values is constructed, in the format of table A3.1:

- estimates are made of 2004 net trade flows in Chinagro classification (commodity volumes, with prices), combining data from the National Bureau of Statistics of China, the Food and Agricultural Organization of the United Nations and earlier Chinagro outcomes[21]
- the 2004 GTAP trade values are expressed in terms of net trade
- the 2004 GTAP non-agricultural trade values are adjusted in order to make the trade surplus consistent with the trade surplus in the Chinagro data set (which originates from the National Bureau of Statistics of China)
- the Chinagro figures provide the column totals of the matrix of net trade values, the GTAP figures the row totals
- initial estimates are made for the distribution of Chinagro trade values over GTAP sectors, largely based on calculations from the UNCTAD TRAINS data base (6-digit HS level)
- the two-dimensional matrix of net trade values is made internally consistent by dedicated adjustments (with, if necessary, the ‘nonfood’ Chinagro column and the ‘other food’ GTAP row as balancing item, although within limits).

Then, the coefficients are calculated from the matrix of net trade values:

- the values are converted into ‘GTAP volume unit’ per ‘Chinagro volume unit’ (for Chinagro we apply the prices mentioned in Table 3.2; for GTAP we automatically have unit prices since the volumes are expressed in constant dollars of 2004)
- coefficients that are initially negative for an agricultural Chinagro commodity are set at zero, with compensation in the other elements (such negative figures arise since GTAP sectors with opposite trade flows can belong to one and the same Chinagro commodity, but they are relatively small).

The results are shown below on the next page in Table A3.2:

[21] The outcomes are shown in Table 3.2 of the main text.

Table A3.2. Mapping matrix from Chinagro to GTAP: coefficients (column wise)

| *Chinagro* / *GTAP* | Rice | Wheat | Maize | Othstaple | Veg.oil | Sugar | Fruits | Vegetab | Rummeat | Pork | Poulmeat | Milk | Eggs | Fish | Chfeed | Protfeed | Nonfood |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ric | 0.291 | | | | | | | | | | | | | | | | |
| Wht | | 0.204 | | | | | | | | | | | | | | | |
| Gro | | | 0.122 | 0.058 | | | | | | | | | | | 0.005 | | |
| V_f | | | | 0.000 | | | 0.133 | 0.281 | | | | | | | 0.012 | | |
| Osd | | | | 0.225 | 0.163 | | | | | | | | | | | 0.047 | -0.044 |
| C_b | | | | | | 0.000 | | | | | | | | | | | |
| Pfb | | | | | | | | | | | | | | | | | -0.071 |
| Ocr | | | | | | | | | | | | | | | 0.000 | | 0.020 |
| Ctl | | | | | | | | | 0.220 | | | | | | | | -0.003 |
| Oap | | | | | | | | | | 0.135 | 0.123 | | 0.860 | | | | -0.013 |
| Rmk | | | | | | | | | | | | 0.000 | | | | | |
| Wol | | | | | | | | | | | | | | | | | -0.021 |
| Cmt | | | | | | | | | 2.068 | | | | | | | | -0.009 |
| Omt | | | | | | | | | | 1.219 | 1.105 | | | | | 3.E-4 | 0.012 |
| Vol | | | | | 0.381 | | | | | | | | | | | 0.008 | |
| Mil | | | | | | | | | | | | 0.290 | | | | | |
| Sgr | | | | | | 0.232 | | | | | | | | | 4.E-4 | | |
| Ofd | | 0.000 | | 0.017 | | | 0.394 | 0.370 | | | | | 0.152 | 0.987 | 0.010 | 0.004 | 0.078 |
| B_t | | | | | | | | | | | | | | | | | 0.012 |
| Fsh | | | | | | | | | | | | | | 0.478 | | | |
| Ext | | | | | | | | | | | | | | | | | -0.611 |
| Txt | | | | | | | | | | | | | | | | | 1.804 |
| Lmf | | | | | | | | | | | | | | | | | 1.519 |
| Hmf | | | | | | | | | | | | | | | | | -1.172 |
| Utl | | | | | | | | | | | | | | | | | 2.E-4 |
| Trc | | | | | | | | | | | | | | | | | -0.186 |
| Osr | | | | | | | | | | | | | | | | | -0.136 |

Units: constant 2004 USD per kg (food) or per Mcal (feed) or per 10 Yuan of 1997 (non-food)

## Annex 4. Convergence of welfare program with world price feedback

**** to be written

## Annex 5. Trade welfare function with distinction of imports and exports

We start from a quasi-linear trade welfare function for the Rest of the World:

$$U(v_1,..,v_{n-1}) + v_n \tag{A5.1}$$

where U a strictly concave, increasing and continuously differentiable function from $\mathbb{R}^{n-1}$ to $\mathbb{R}$, and $v_k$ net imports of commodity *k* by the Rest of the World.

For the quadratic specification

$$U(v) = bv - \frac{1}{2} v^T Av \tag{A5.2}$$

where $b \in \mathbb{R}_{++}^{n-1}$ and the $(n-1)\times(n-1)$ matrix A symmetric and strictly positive definite, one gets $U'(v) = b - Av$ and, following equation (2.3):

$$p^w = \overline{p}_n^w (b + Az) \tag{A5.3}$$

In this case the world price equations are linear with a positive intercept. Whether *U* increases and, hence, $p^w$ is non-negative, is not guaranteed in this specification but should be ensured by the estimated coefficients on the relevant range of values of net imports z.

Consider alternatively:

$$U(v) = bv - \frac{1}{2} v_1^T A^e v_1 - \frac{1}{2} v_2^T A^m v_2 \tag{A5.4}$$

where $b \in \mathbb{R}^{n-1}$ a positive vector, the $(n-1)\times(n-1)$ matrices $A^e$ and $A^m$ symmetric and strictly positive definite, and $v_{1k} = max(v_k, 0)$ and $v_{2k} = -min(v_k, 0)$ for $k=1,..,n-1$.

Then, *U* is continuously differentiable (for $v > 0$ and $v < 0$ it is straightforward but it applies also when $v_k = 0$ for some *k* due to the equality of lefthandside and righthandside derivatives) but **** is *U* also concave or even strictly concave?

Anyhow, $U'(v) = b - A^e v_1 + A^m v_2$ (sign change last term due to differentiation from $v_2$ to *v*) and then application of equation (2.3) gives by substituting $v = -z$ :

$$p^w \big/ \overline{p}_n^w = b - A^e\, max(-z, 0) + A^m\, max(z, 0) \tag{A5.5}$$

where the max-operators apply to each element of the $(n-1)$ dimensional vectors.

The single-commodity case of (A5.4) is

$$U(v) = \sum_k \left( b_k v_k - \frac{1}{2} a_k^e {v_{1k}}^2 - \frac{1}{2} a_k^m {v_{2k}}^2 \right) \qquad \text{(A5.6)}$$

where again $v_{1k} = max(v_k, 0)$ and $v_{2k} = -min(v_k, 0)$ for $k=1,..,n-1$, whereas scalars $b_k$, $a_k^m$ and $a_k^e$ are positive. In this case, one can prove that $U$ is not only continuously differentiable but also strictly concave (e.g. by drawing the graph of the quadratic terms). Differentiation gives:

$$\partial U / \partial v_k (v) = b_k - a_k^e v_{1k} + a_k^m v_{2k}$$

and, hence, by applying (2.3) and substituting $v_k = -z_k$:

$$p_k^w / \bar{p}_n^w = b_k - a_k^e \, max(-z_k, 0) + a_k^m \, max(z_k, 0) \qquad \text{(A5.7)}$$

This formulation coincides with the two-branch specification for single commodities of section 5:

$$p_k^w / \bar{p}_n^w = b_k + a_k^m z_k \qquad for \; z_k \geq 0 \qquad \text{(A5.8a)}$$

$$b_k + a_k^e z_k \qquad for \; z_k < 0 \qquad \text{(A5.8b)}$$

for positive slopes $a_k^m, a_k^e$ and intercept $b_k$. This function is increasing, continuous (due to the common intercept) and linear with a kink. Non-negativity must be ensured by the estimated coefficients on the relevant range of values of net imports $z$.

## Annex 6. Estimation of a linear system with parameter constraints

Here, we outline the estimation of a linear system with constraints on the parameters. Consider:[22]

$$p^w = b + Az + u \tag{A6.1}$$

where $b \in \mathbb{R}^{n-1}_{++}$ and the $(n-1)\times(n-1)$ matrix $A$ symmetric and strictly positive definite. Observations are available for the $(n-1)$ dimensional vectors $p^w$ and $z$, while the $(n-1)$ dimensional vector $u$ is a vector of error terms.

We define $m = n\text{-}1$ and consider observations $s = 1,\ldots,S$ :

$$p^w_s = b + Az_s + u_s \tag{A6.2}$$

in which $p^w_s, b, z_s, u_s \in \mathbb{R}^m$ and matrix $A$ is $m \times m$. Restrictions: $b > 0$, $A$ symmetric and positive definite.

Further notation:

$b_k$ element k of vector $b$ $(k = 1,\ldots,m)$

$A_k$ row k of matrix $A$ $(k = 1,\ldots,m)$

$p^w_{ks}$ element k of vector $p^w_s$ $(k = 1,\ldots,m)$

$u_{ks}$ element k of vector $u_s$ $(k = 1,\ldots,m)$

Hence:

$$p^w_{ks} = b_k + A_k z_s + u_{ks} \tag{A6.3}$$

The following properties of $u_s$ are assumed:

a) $Eu_s = 0$, $Eu_s u_s^T = \Omega$ with the $m \times m$ matrix $\Omega$ symmetric and positive definite

b) $u_s$ *and* $u_{s'}$ independent for $s \neq s'$.

In addition, one may or may not assume normality. Here, we do not do it and apply the estimation method of Generalized Least Squares (see Davidson-McKinnon, section 9.8). However, we also have to take into account also the restrictions on the parameters $b$ and $A$. Therefore, we write

$$A = \rho\Lambda + (1-\rho)\Sigma \tag{A6.4}$$

[22] Compared to the main text of section 6, we use $A$ for $A^e$ respectively $A^m$, and we neglect $\overline{p}^w_n$.

in which

| | |
|---|---|
| $\Lambda$ | diagonal $m \times m$ matrix with elements $\lambda_k > 0$ for $k = 1,..,m$ |
| $\Sigma$ | symmetric $m \times m$ matrix with elements $\sigma_{kk'}$ for $k, k' = 1,\ldots,m$ |
| $\rho$ | fixed scalar, $\in (0,1)$ and large enough to guarantee positive definiteness of $A$ |

Then, extending the GLS approach of Davidson-MacKinnon, estimation can proceed in four steps:

i) obtaining a consistent estimate $\hat{\Omega}$ of covariance matrix $\Omega$
ii) applying GLS (using $\hat{\Omega}$) to determine $b, \Lambda$ *and* $\Sigma$
iii) checking whether $b > 0$ and $A$ positive definite
iv) deriving test statistics (Likelihood-Ratio) for the parameter estimates.

These steps are summarized below, one by one.

Ad i) Estimating $\hat{\Omega}$

- estimate (A6.3) for each commodity *k* separately, via OLS
- calculate residuals $\hat{u}_{ks}$
- define $\hat{U}$ as the $m \times S$ matrix with elements $\hat{u}_{ks}$
- then, $\hat{\Omega} = \frac{1}{S} \hat{U}\, \hat{U}^T$ or $\hat{\omega}_{kk'} = \frac{1}{S} \sum_{s=1}^{S} \hat{u}_{ks} \hat{u}_{k's}$
- determine $\hat{\Omega}^{-1}$

Ad ii) Estimating $b, \Lambda$ *and* $\Sigma$ via GLS

- minimize the generalized sum of squared residuals

$$\sum_{s=1}^{S} [\, p_s^w - b - (\rho\Lambda + (1-\rho)\Sigma) z_s \,]^T \; \hat{\Omega}^{-1} [\, p_s^w - b - (\rho\Lambda + (1-\rho)\Sigma) z_s \,] \qquad \text{(A6.5)}$$

Ad iii) Checking parameter conditions

- check whether $b_k > 0$ for all *k*
- check whether $\lambda_k > 0$ for all *k*
- check whether matrix A is positive definite, by calculating eigenvalues or solving:

$$\min_{x \in \mathbb{R}^m} x' A x \quad s.t. \; \| x \| = 1$$

Ad iv) Deriving Likelihood-Ratio test statistics

- define the sum of squared residuals $SSR(b,\Lambda,\Sigma)$ as
  $$\sum_{s=1}^{S} (p_s^w - b - (\rho\Lambda + (1-\rho)\Sigma)z_s)^T \hat{\Omega}^{-1} (p_s^w - b - (\rho\Lambda + (1-\rho)\Sigma)z_s)$$

- calculate
  $$s^2 = SSR(\hat{b},\hat{\Lambda},\hat{\Sigma}) / (mS - 2m - m(m+1)/2) \qquad \text{(A6.6)}$$

  in which $mS$ the number of observations and $2m+m(m+1)/2$ the number of parameters

- to test whether one of the parameters is zero, define $(\breve{b},\breve{\Lambda},\breve{\Sigma})$ as restricted estimate (obtained with the parameter concerned kept at zero) and calculate the test statistic

  $$[SSR(\breve{b},\breve{\Lambda},\breve{\Sigma}) - SSR(\hat{b},\hat{\Lambda},\hat{\Sigma})] / s^2 \qquad \text{(A6.7)}$$

  which has asymptotically a $\chi^2(1)$ distribution (Davidson-MacKinnon, section 3.6 and 5.7)

  Thus, in order to test all parameters, the generalized sum of squared residuals must be minimized first without restrictions and subsequently $2m+m(m+1)/2$ times with each time one of the parameters kept at zero.

Final remark: in case of problems in minimizing (A6.5), we may alternatively try it via Cholesky-decomposition of the inverse covariance matrix, as follows

- determine a nonsingular triangular $m \times m$ matrix $\Psi$, with elements $\psi_{kk'}$, such that $\Psi^T \Psi = \hat{\Omega}^{-1}$ (see Davidson-MacKinnon, section A.7, for the derivation)
- premultiply left- and right-hand side of (A6.1) with $\Psi$:
  $$\Psi p_s^w = \Psi b + \Psi A z_s + \Psi u_s \qquad \text{(A6.8)}$$
- define $\tilde{u}_s = \Psi u_s$, then:

$$E\tilde{u}_s = 0,\ E\tilde{u}_s \tilde{u}_s{}^T = \Psi (E u_s u_s{}^T) \Psi^T = \Psi\Omega\Psi^T = \Psi(\Psi^T\Psi)^{-1}\Psi^T = \Psi\Psi^{-1}(\Psi^T)^{-1}\Psi^T = I$$

- substitute (A6.4) in (A6.8):
  $$\Psi p_s^w = \Psi b + \Psi(\rho\Lambda + (1-\rho)\Sigma)z_s + \tilde{u}_s \qquad \text{(A6.9)}$$
- estimate $b, \Lambda$ *and* $\Sigma$ from (A6.9) with univariate Nonlinear Least Squares (NLS).